A new classification of feldspars by luminescence spectral techniques

J. Garcia-Guinea[1], L. Sanchez-Muñoz [2] & V. Correcher [2]

[1]Museo Nacional Ciencias Naturales, C/ Jose Gutierrez Abascal 2 Madrid 28006 Spain, guinea@mncn.csic.es
[2]Dpto. Dosimetria de Radiaciones. Ciemat, Av. Complutense 22 Madrid 28040 Spain

ABSTRACT

The proposed luminescence classification of feldspars is found on the relationships between feldspar lattice defects and their coupled spectra luminescence peaks. The UV emission at 290 nm is linked with the presence of Na and cracks-strain-exsolution-twinning; at 340 nm with stress in Si—O bonds; the broad blue band (380-450nm) with $[AlO_4]^o$ defects; at 560nm with Mn^{2+} point defects and at 720nm with iron in the lattice. The feldspar classification here provided can be used as a practical guideline for pegmatite feldspar studies since the luminescence techniques are sensitive tools detecting defects.

INTRODUCTION

The feldspar spectra luminescence emission is an optical property not simply based on local average structure but depends on their original genetic media, i.e. impurities in the crystals, and on later transformations, such as structural strain and aqueous alterations. These data can also be detected by other powerful analytical techniques, e.g., X-ray diffraction or HRTEM to classify feldspars by their chemical, structural, textural and genetic features. Luminescence properties have not been used to separate feldspars in groups with characteristic behaviour. In addition, these data are commonly used in geological dating (Huntley et al., 1985). Traditional classifications of feldspars, based on X-ray diffraction patterns and textures are worldwide used but have not been correlated with the extended phenomenon of the anomalous fading of the luminescence emission in feldspars or radiation sensitivity. This classification will bring: (i) certainty in sampling and experimental design of analytical luminescence routines for dating and dosimetric purposes; (ii) information relative to impurity contents (activators) to be used as a criteria for recognition of rare metal deposits in pegmatites (Boroznovskaya et al. 1996); (iii) methodology to study fluid flow paths linked with the distribution of the blue luminescence using CL techniques (Mora and Ramseyer, 1992). Furthermore, feldspar specimens collected from pegmatite bodies have excellent conditions of purity, big size, crystallinity and perthite exsolution to be used in spectra luminescence studies. Additionally, we have also studied transparent samples of sanidine, cleavelandite-albite and adularia to obtain clean spectra.

EXPERIMENTAL

A set of well-characterized feldspar samples, i.e., adularia, microcline, orthose, low albite, monalbite, perthite, sanidine, labradorite oligoclase, amorphous KAlSi3O8 gel, feldspar glass, preheated and Na-exchanged K-feldspars, were analysed in the high-sensitivity thermoluminescence spectrometer (Univ. of Sussex, UK). This spectrometer self-device records photonic intensity versus spectra versus temperature providing in situ irradiations, e.g. IR, UV, X-ray, and electron-beam, which create different traps and recombination centres (Luff & Townsend, 1993).
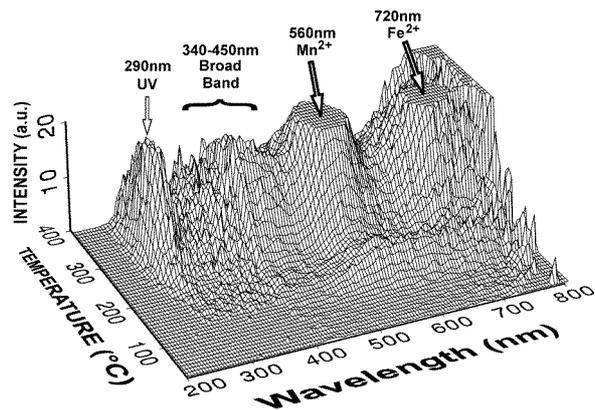

FIGURE 1. Three-dimensional plot of the spectra thermoluminescence emission (vs temperature versus wavelength vs photonic intensity) of a natural LS205 albite of brown colour collected from the Verdugal pegmatite body, Colmenar Viejo, Spain. Note the characteristic spectra luminescence bands of alkali feldspars at 290, 340, 380-450, 560 and 720 nm.

PROPOSED CLASSIFICATION

The classification of feldspar samples here suggested under the spectral luminescent techniques point of view is as follows:

Feldspars with low emission

Iron-rich feldspars.- Luminescence emissions at longer wavelengths, i.e, 560 nm & 750 nm stem from point defects of Mn^{2+} and Fe^{3+} in feldspar lattices. Furthermore, high amounts of these impurities (e.g. 0.3%) lower these light emissions. Dark and iron-rich samples emit weak luminescence signals.

Unstrained plagioclases.- Plagioclase feldspars have characteristic deformation mechanisms, such as anthiphase domains and mechanical twinning probably linked with their low UV emissions. Mechanical twinning is the most common deformation mechanism in plagioclases and it has never been found in K-feldspars. In addition, under heating-irradiation pre-treatments calcium escapes less readily from the lattices, causing less sensitization on the broad blue band circa 420nm.

Authigenic feldspars.- Authigenic feldspars show very weak or no cathodoluminescence (CL), whereas allochthonous feldspars formed at high temperature show CL emission (Marshall, 1987). Authigenic K-feldspar has low sodium content and never displays transformation twinning (Smith 1974). In equilibrium

conditions, the increase of formation temperature augments the Na solubility in the K-feldspar lattice. The Na solubility in normal structural sites is limited and the extra-contents of Na accumulates in the twinning interfaces. For this reason, the twin density increases with temperature.

Feldspars with high emission

Annealed strain-free feldspars, e.g. Sanidine, adularia, artificially preheated feldspars. These type of samples are meta-stable feldspar quenched from high temperatures, since above $600°C$ a clear homogenization occurs. The common spectra emission is a strong broad band at approximately 380-450nm. Two steps are necessary to obtain this large blue emission band: (i) a thermal sensitization of the lattice by strong heating-time periods (starting at approximately $600°C$) and (ii) activation of emission centres under short wave radiations such as, X-ray, gamma, or UV. The same effect has been described in quartz where prolonged high-temperature annealing reduces the presence of ionic charge compensators at the Al sites and induces an intense 380nm emission to $[AlO_4]°$ centres (Martini et al., 1995). Alkali feldspar lattices are sensitized, by thermal leakage of alkali ions from very low temperature-time doses, (e.g. $80°C$ for a few minutes to above $1400°C$ for several months). These processes obviously involve Na^+, K^+, OH^-, H^+ and H_2O exchanges with the environment and iron redox reactions which modifies the spectra luminescence emission.

Strained coherent exsolved feldspars, e.g., microcline, orthoclase, albite and perthite. In alkali feldspars, the characteristic subsolidus exsolution circa 600ºC separates Na and K phases producing perthite textures. In crypto-perthite textures, the structures are a continuous throughout the lamellar interface and the coherent exsolution involves elastic stresses and strains in the phases. Coherent exsolved feldspars show UV emissions (290nm/340 nm) with the following characteristics: (i) They have been linked with the presence of $NaAlSi_3O_8$ phases in the sample (Garcia-Guinea et al., 1999; (ii) The close association between twinning and the UV band (290 nm) in K-feldspar points to charge trapping and light emissions from complexes of structural defects located at the twin-domain boundaries. The high-temperature slope of the TL glow curve follows a power -law decay, suggesting possible trapping-detrapping dynamics related to cooperative phenomena inside the complexes Sanchez-Muñoz et al., (2006a), (iii) The artificial thermal Na exchange from potassium phases produces a large radioluminescence emission at 320 nm Garcia-Guinea, et al., 1999, (iv) A 340 nm emission peak in the luminescence spectra of tectosilicate minerals, e.g., groups of silica, feldspars, feldspathoids, could be observed when the 3D-framework silicon-oxygen lattices is stressed. The Si-O strained structures include some non-bridging oxygen or silicon vacancy-hole centers, and Si-O bonding defects which seem to be responsible for the 340 nm emission. This classification

encloses some additional difficulties, for instance, the UV emission (290nm) has a cluster relationship with other bands (i.e. 340nm) explained by links among defects. During the thermal self-diffusion processes the alkali ions most probably leaked along the easier exists (planar defects) and conversely, the atomic transport along interface-interphases destabilizes the metastable equilibrium of the twin-domains and unmixed phases. Furthermore, the new spatially-resolved CL devices coupled into SEM chambers allow visualize the blue luminescence emitted from radiation-induced O-defects, the other spectra luminescence bands and the mineralogical characteristics of twinning and exsolution of perthite textures, e.g., a microcline from the Golconda III granitic pegmatite of Minas Gerais, Brazil (Sanchez-Muñoz, 2006b).

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